Design of octupole channel for IOTA

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Purpose of the channel

On the first stage of experiment on nonlinear dynamics at IOTA the nonlinearity will be created by an octupole channel. The channel occupies a space of a 1.8-meter-long special nonlinear magnet (being developed by Radiabeam and to be used on next stages). Octupole field, created by the channel, is equal to the 4th harmonic of nonlinear field, created by the special magnet. Numerical simulation predict that using this approach one could gain a betatron frequency shift of up to 0.08 with dynamical aperture of 20σ for electron beam at IOTA.
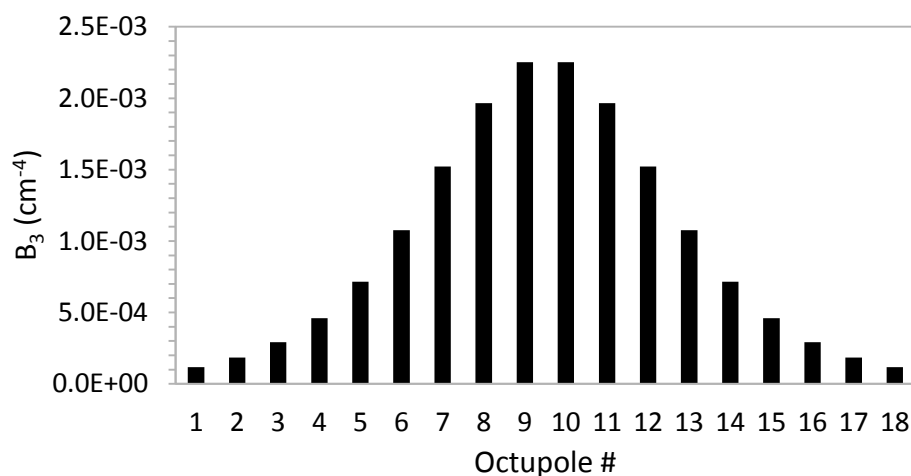

Figure 1: Example distribution of normalized octupole strength in the channel.
Magnetic length of each octupole – 10 cm.

Key requirements, assumptions, and constraints

- Strength of the octupoles shall be sufficient to reach dynamical aperture limitation in experiments. That translates into at least 1.3 kG/cm^3 octupole gradient[1]
- Magnetic length of the device should be 180 cm. Simulations predict that splitting it into 20 short octupoles, each with its own strength (see fig. 1), gives big (20σ) dynamic aperture, while requiring a relatively small number of magnets.
- Numerical modelling shows that field quality at the level of 10% is sufficient

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[1] Octupole gradient is defined as the third derivative of magnetic field: $\dfrac{\partial^3 B_y}{\partial x^3}$.

- Physical aperture shall not be restricted significantly. Beam pipe diameter is 1" throughout the channel
- Amount of required power supplies has to be minimized
- Octupoles will operate with 10V/2A power supplies
- Octupoles have to be air-cooled
- 2D modelling of magnetic field shows that the steel is far from saturation because of the small magnitude of the field: less than 1 kG at pole tips. No special requirements on the quality of magnetic steel is needed.

Design and specifications

The channel will have 18 air-cooled conventional octupole magnets, powered in pairs. Anticipate a usage of 10V/2A switchable polarity power supplies. The design of the octupoles, inspired by ATF octupole, provides a simple low-cost solution for the channel. Figure 2 shows a drawing of the octupole and Table 1 summarizes its main specifications.
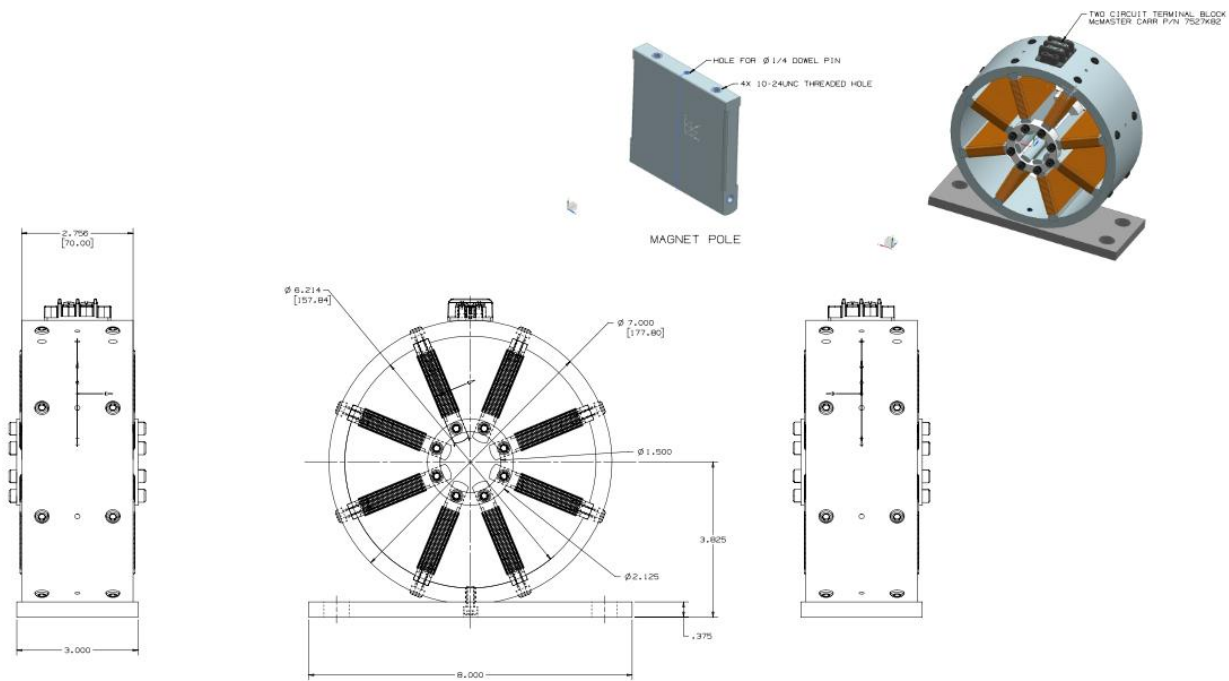

Figure 2: 3D model and drawings of IOTA octupole. Picture provided by S. Wesseln

Table 1: Requirement specification. Items highlighted in yellow need to be checked or can be adjusted.

1	Number of octupoles	18
2	Spacing between the centers of the octupoles	10 cm
3	Pole length	7 cm
4	Magnetic length	10 cm
5	Distance between the poles	28 mm
6	Beampipe diameter	1"
7	Integrated current	170 A-turns
8	Coil current	Not more than 2 A
9	Number of coil turns	85-90
10	Voltage drop per pole	Not more than 0.625 V
11	Voltage drop per magnet (poles in series)	Not more than 5 V
12	Coil diameter	1.0 mm
13	Power consumption (per magnet)	Less than 10 W
14	Max octupole gradient	At least 1.3 kG/cm^3
15	Field uniformity	0.1 or better
16	Precision of position of pole tips	0.5 mm or better